(12) UK Patent Application (19) GB (11) 2 121 226 A

(21) Application No 8310013
(22) Date of filing 13 Apr 1983
(30) Priority data
(31) 57/061381
57/061382
57/062924
(32) 13 Apr 1982
13 Apr 1982
15 Apr 1982
(33) Japan (JP)
(43) Application published
14 Dec 1983
(51) INT CL³
G02F 1/137
(52) Domestic classification
G5C A342 HG
G2F 23E 24T 25A 25F
25P2 CT
(56) Documents cited
GBA 2030720
GBA 2023866
GBA 2023865
GBA 2023864
GBA 2002943
US 4002404
US 3966304
(58) Field of search
G5C
G2F

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(54) Liquid crystal display

(57) A liquid crystal display device utilizing the guest-host mode has liquid crystal material containing added dichroic dye between a pair of substrates (5, 6) carrying electrodes (7, 8), with homogeneous alignment layers on one region (9) producing homogeneous or twisted alignment, and homeotripic alignment layers on another region (10). Alternatively the homogeneous or twisted region may be replaced by a hybrid alignment region, with a homogeneous layer on one face opposed to a homeotropic layer on the other. Positive colour display with the advantageous positive dielectric anisotropic liquid crystal material is then practical. The cell may have reflective layer (6) and polarizer (P).

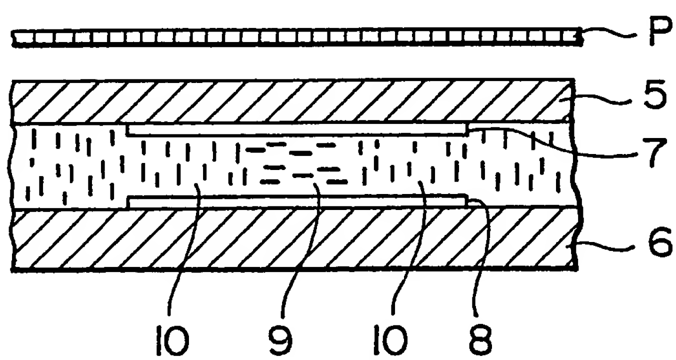

FIG. 2B

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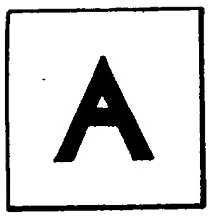


FIG. 1A

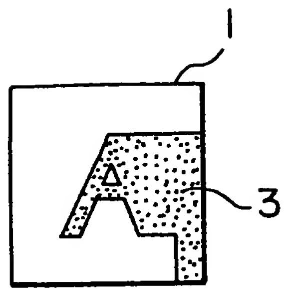


FIG. 1B

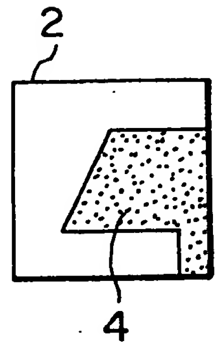


FIG. 1C

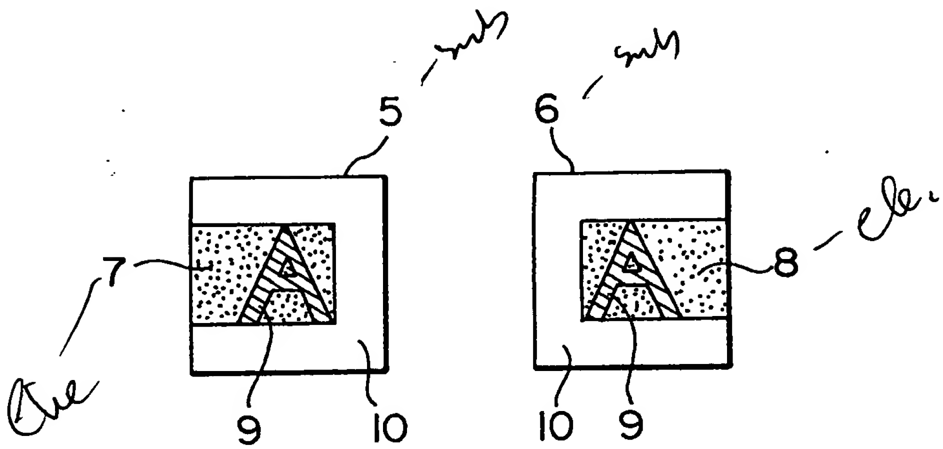


FIG. 2A

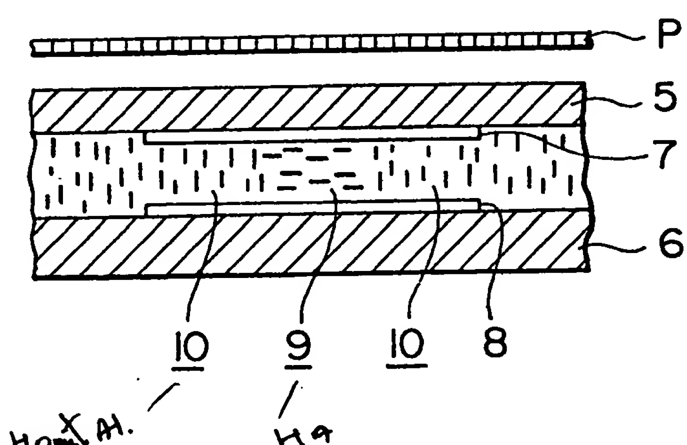


FIG. 2B

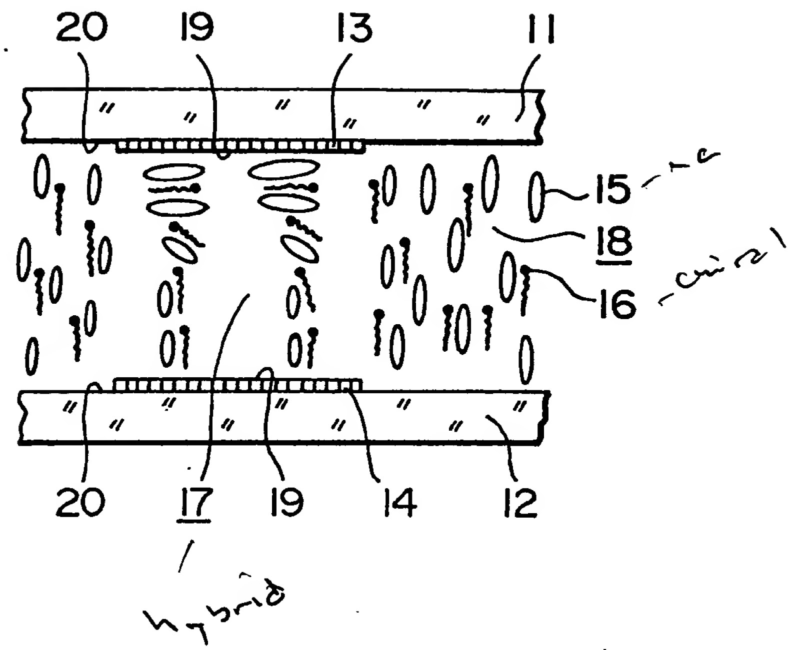


FIG. 3

FIG. 4A

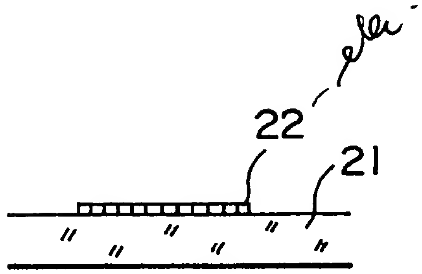


FIG. 4B

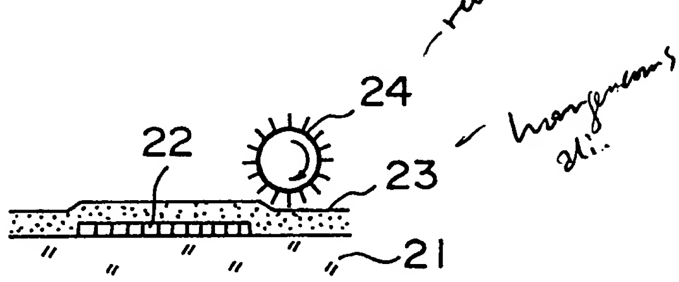


FIG. 4C

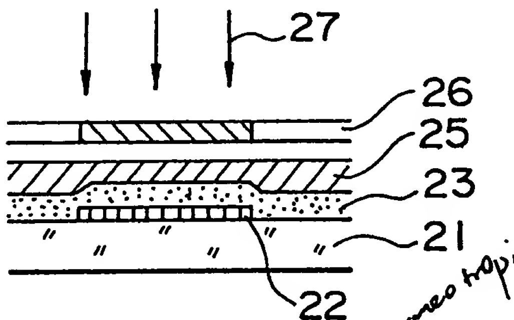


FIG. 4D

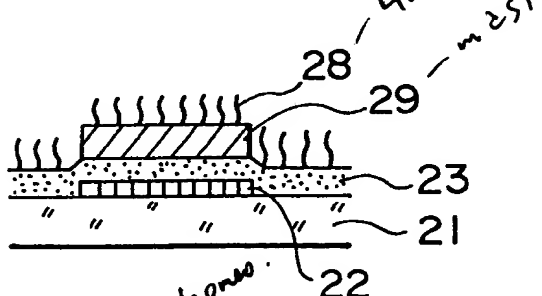
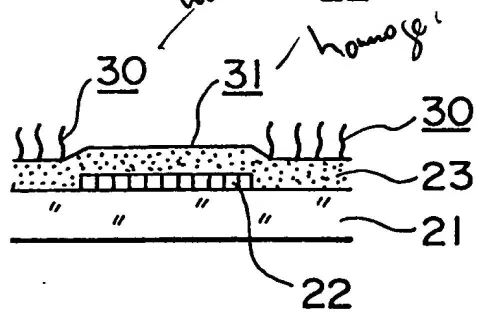


FIG. 4E



SPECIFICATION

Electrooptical device.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an electrooptical device employing a liquid crystal, and more particularly, to a guest-host type liquid crystal display device utilizing a dichroic dye.

Description of the Prior Art

A mode of liquid crystal display known as the guest-host mode is a technique of changing the molecular alignment of a dichroic dye incorporated in a nematic liquid crystal by utilizing the fact that the molecular alignment direction of the liquid crystal changes upon application of an electric field. This mode is described, for example, in "Applied Physics Letters", Vol. 13, No. 3, pp. 91—92 (Aug. 1968) and "Electro-Technology", pp. 45—46 (Jan. 1970).

For achieving a positive display (formation of a colored pattern on a colorless or light-colored background) in the guest-host mode, it is necessary that a dichroic dye is added to a nematic liquid crystal having a negative dielectric anisotropy (Nn liquid crystal) and this liquid crystal is brought to homeotropic alignment. The colorless or light-colored state under the non-electric field condition can be converted into the colored state by application of the electrical field. However, the Nn liquid crystals require high voltage for operation and have high viscosity, thereby raising some problems in the performance. In contrast, a nematic liquid crystals with positive dielectric anisotropy (Np liquid crystals) can be operated at a lower voltage and is lower in the viscosity, thereby permitting very quick response display even at low temperatures. For achieving a positive display by use of this Np liquid crystal, for example, for forming the display pattern "A" shown in Fig. 1A, the electrodes 3 and 4 formed on the substrates 1 and 2 are subjected to homogeneous alignment treatment only in the areas of the electrodes corresponding to the pattern "A", and the other areas are subjected to homeotropic alignment treatment. In this case, the display pattern as shown in Fig. 1A can be formed under the non-electric field condition, and the display pattern "A" can be eliminated by applying an electric field to effect the positive display.

According to this prior art, however, it is necessary to make the electrodes 3 and 4 completely opposed to each other so that they may be exactly registered. If there is positional discrepancy in the registration, the Np liquid crystal present in the discrepancy region will be different in the alignment mode from that present in the other region. As a result, the marginal portion of the display pattern "A" is not eliminated even upon application of the electric field and undesirably remains as a display pattern. In addition, the registration of the upper and lower electrode patterns with a very high accuracy causes lowering of production yield and difficulty in wiring.

SUMMARY OF THE INVENTION

In one aspect the present invention aims to provide an electrooptical device in which a dichroic dye and liquid crystal are disposed and which is able to perform color positive display in the guest-host mode.

In another aspect the invention aims to provide an electrooptical device comprising a dichroic dye and liquid crystal which is suitable for performing color positive display in the guest-host mode.

In a further aspect this invention aims to provide an electrooptical device, two electrode substrates of which can be easily registered in proper positions with a high accuracy in making the device.

In yet another aspect this invention aims to provide an electrooptical device with which very fine display or complicated display can be made.

In a still further aspect this invention aims to provide a process for making an electrooptical device with good yield and markedly improved productivity.

According to the intention, there is provided an electrooptical device comprising a liquid crystal and a dichroic dye disposed between a pair of opposed electrode substrates, characterized in that the liquid crystal has a homogeneous alignment region or twisted alignment region and a homeotropic alignment region.

According to the invention, there is also provided an electrooptical device comprising a liquid crystal and a dichroic dye disposed between a pair of opposed electrode substrates, characterized in that said liquid crystal has a homogeneous alignment or twisted alignment region and a hybrid alignment region.

According to the inventi n, ther is also provided a process f r making an electrode substrate for use in an electrooptical device comprising the steps of; f rming a ph t resist coating on an el ctrode substrate having a h mogene us aligning film, exposing and developing th ph toresist c ating to form a mask, forming a homeotropic aligning film on the lectrode substrate having the homogeneous aligning film and th mask, and removing the mask.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A thr ugh 1C are plane views of an electrooptical device of th prior art. Fig. 2A is a plane

view of a pair of electrode substrat s for an electrooptical device of this invention. Fig. 2B is a cross-sectional view of an electrooptical device employing the electrode substrates as shown in Fig. 2A. Fig. 3 is a cross-secti nal view f another mbodiment of the lectrooptical device acc rding t this invention. Figs. 4A through 4E ar cross-sectional views for illustrating st ps of th process for making an electrooptical device of this invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

According to this invention, in utilizing a liquid crystal and a dichroic dye dissolved therein in the guest-host mode color display, two sheets of electrode substrates, each having a homogeneous aligning-treated area and a homeotropic aligning-reated area, are disposed so as to be opposed to each other, and the liquid crystal in which the dichroic dye is dissolved is placed between the electrode substrates, thereby providing a desired electrooptical device.

In the electrooptical device of this invention, the direction of the homogeneous aligning treatment in one electrode and that in the other electrode opposed to the one electrode can be crossed at an angle of 90° to each other, whereby the liquid crystal disposed between the electrodes can be put into twisted alignment mode.

Further, one electrode opposed to the other electrode to which the homogeneous aligning treatment is applied can be subjected to a homeotropic aligning treatment, whereby the liquid crystal disposed between the electrodes can be put into hybrid alignment.

The homogeneous aligning treatment used in this invention can be accomplished by known methods, for instance, by forming a coating film of SiO, SiO_2, TiO_2, polyimide, polyamide, polyester, polycarbonate, polystyrene, poly(vinyl chloride), or the like on the substrate having a display electrode and rubbing the coating film with a usual cloth, velvet, or other fabric; or alternatively by forming a coating film of the above-cited material thereupon by the oblique evaporation method. The liquid crystal in contact with the homogeneous aligning-treated electrode can be brought to the homogeneous alignment.

The homeotropic aligning treatment can also be accomplished by known methods, for instance, by coating the substrate having a display electrode with a homeotropic aligning film-forming material comprising a fluorine-containing silane compound such as

$$CF_3(CF_2)_3{-}Si{\equiv}(OCH_3)_3,\ CF_3(CF_2)_4{-}Si{\equiv}(OCH_3)_3,$$
$$CF_3(CF_2)_5{-}Si{\equiv}(OCH_3)_3,\ CF_3(CF_2)_6{-}Si{\equiv}(OCH_3)_3,$$

or the like, followed by a heat treatment. The liquid crystal in contact with the homeotropic aligning-treated electrode will assume homeotropic alignment mode.

Formation of both homogeneous aligning-treated area and homeotropic aligning-treated area on the same, one electrode can be accomplished, for example, by the screen printing method.

Dichroic dyes uses in this invention may include, for example, anthraquinone type dyes, cyanine type dyes and azo types dyes.

Any type of liquid crystals, nematic, cholesteric, or smectic liquid crystals may be used in this invention. Preferred ones are nematic liquid crystals having positive dielectric anisotropy (Np liquid crystals) and those having negative dielectric anisotropy (Nn liquid crystals). Np liquid crystals may include, for example, phenylcyclohexane type, phenylcyclohexane ester type, biphenylcyclohexane type, biphenylcyclohexane ester type and terphenyl type liquid crystals. Nn liquid crystals may include, for example, azoxybenzene type and N-(benzylidene)aniline type liquid crystals. With respect to smectic liquid crystals, phases A, B, C and H thereof can be used, but particularly suitable ones are of phases C and H.

Referring now to the drawings, this invention is described in detail.

Figs. 1A, 1B and 1C illustrate patterns of electrodes formed on the upper and lower substrates of a prior art liquid crystal display. An electrode pattern 3 is formed on the upper substrate 1, and an electrode pattern 4 on the lower substrate 2. In this type of cell, since the display pattern is only a portion where the upper and lower electrode patterns are exactly overlapped, the positional difference between the electrode patterns should be kept minimum.

Fig. 2A is a plane view of a pair of electrode substrates in an embodiment of this invention. Fig. 2B is a cross-sectional view of this embodiment. In this embodiment, the electrode 7 on the upper substrate 5 and the electrode 8 on the lower substrate 6 may be both very simple in shape. The electrode 7 is treated to form a homogeneous alignment area 9 on part of the surface, and the remaining surface is formed into a homeotropic alignment area 10. At this tim , the homeotropic alignment area 10 on the non-el ctrode surfac is dispensable. A liquid crystal display cell may be made, f r example, in such a manner that the upper and l wer el ctrode substrates 5 and 6, each having the h mogeneous alignment treatment ar a 9 and homeotropic alignment treatm nt ar a 10 as shown in Fig. 2A, are superposed so that the display electrode 7 and pposite electrode 8 may opposed t each other, and thereafter a cell assembling is conducted in a conventional mann r, and further an Nn liquid crystal containing a dichroic dy is placed in the cell. In this liquid crystal cell, when no voltage is applied, the color of the dichroic dy can be observed at the display surfac having the homogen ous

aligning-tr ated area 9, whil the display surface having the h me tropic aligning-treated area 10 is col rless. When a voltag is applied, the colorless display surface turns colored, while the display surface having been col r d under the non-voltage application condition becomes col rless.

In this invention, an Np liquid crystal can also b mployed similarly. A polarizing plate, as shown by P in Fig. 2B, can be disposed on the incident light side of the liquid crystal cell. Further, a reflecting plate can be provided if necessary, for the purpose of utilizing the cell as a reflection type.

In this invention, by the above-mentioned constitution, a desired display pattern can be obtained in the colorless or light colored background similarly to the prior art, and when it is to be eliminated, the elimination can be made possible by application of a voltage.

In Figs. 1B and 1C, and Fig. 2A, the upper and lower electrode substrates as seen from the electrode side are illustrated. When the upper and lower electrode substrates are arranged in assembling a display cell, both electrode surfaces are made opposed to each other. Fig. 3 is a cross-sectional view of a display panel according to another embodiment of this invention. A display electrode 13 is provided on the upper glass substrate 11, and a common electrode 14 on the lower glass substrate 12. The surface of the upper glass substrate 11 is subjected to a homogeneous aligning treatment, and then to a homeotropic aligning treatment with the display electrode 13 covered with a desired mask. As a result, a homogeneous aligning-treated surface 19 and a homeotropic aligning-treated surface 20 are formed on the upper glass substrate. The entire surface of the lower glass substrate 12 is treated by the homeotropic aligning treatment to form a homeotropic aligning-treated surface 20.

Thus, the liquid crystal molecules 15 and dichroic dye molecules 16 can form a hybrid alignment region 17 between the display electrode 13 and the common electrode 14, while they can form a homeotropic alignment region 18 in the other portion between the upper and lower substrates. In the hybrid alignment region 17, the alignment direction of the liquid crystal and dichroic dye molecules continuously changes from parallel to perpendicular to the upper and lower substrates as their positions depart from the display electrode 13 and approach to the common electrode 14. That is, the partial hybrid alignment is obtained.

In a liquid crystal display device of this invention, a hybrid alignment region and a homeotropic alignment region can be formed in the liquid crystal placed between the opposed electrodes. For instance, the surface of one electrode is treated to convert it into a homeotropic alignment surface, and the surface of the other opposed electrode is divided into a homeotropic alignment-treated area and a homogeneous alignment-treated area. One substrate is overlaid on the other substrate so that the two electrode surface may be opposed, and a liquid crystal is disposed in the gap between the substrates, whereby a hybrid alignment and homeotropic alignment can be given in the liquid crystal placed between the electrodes. At that time, when an Nn liquid crystal or Np liquid crystal is used, the display state of the hybrid alignment region is shown in the following table.

Type of liquid crystal	Voltage "ON"	Voltage "OFF"
Nn	Colorless	Colored
Np	Colored (deep)	Colored (light)

When an Nn liquid crystal is employed, the two stage display is effected, and the operating voltage can be decreased.

Figs. 4A—4E illustrate steps of the process for making an electrooptical device of this invention.

A homogeneous aligning film-forming material, for example, a solution of silicon compound in an alcohol, "OCD" (mfd. by Tokyo Oka Co., Ltd.), is first applied by spinner coating onto a substrate 21 on which an electrode pattern 22 has been formed, and is heated at 300°C for 1 hour to form a SiO_2 coating film. The coating surface is rubbed unidirectionally with cotton, gauze, or the like 24. Thereby, a homogeneous aligning film 23 is formed. In this case, the direction of rubbing the SiO_2 coating film formed on the counter electrode substrate may be changed in an angle of 90° from the direction of rubbing the above SiO_2 coating film for the purpose of controlling the molecular alignment of the liquid crystal to the twisted alignment state.

Secondly, a positive type photoresist, for example, AZ—1350J (mfd. by Shipley Co.) or OFPR—77 (mfd. by Tokyo Oka Co., Ltd.) is appli d as a photoresist 25 by spinner coating ont the SiO_2 film, heated at 80°C for 10 minut s, and xp s d to light 27 through a prescribed pattern of mask 26 to harden the exposed portions. The photoresist film is developed with AZ developer (mfd. by Shipley Co.) and dried to expose a prescribed pattern of the SiO_2 film, leaving the photoresist coating (mask 29) in the other portion. A solution of a homeotropic aligning film-forming mat rial, for instance, a fluorine-c ntaining silane compound in a solvent which do s not erode the ph toresist, i.e. is inert thereto [.g. a fluorine containing compound FS—116 (a Daifron solution, mfd. by Daikin Chem. Co., Ltd.) or SRX—679 (mfd. by Toray Silicone Co.) as diluted with pure water] is applied by spinner coating onto th r sulting

surface and dried at 80—200°C to form a homeotropic aligning film 28. After a prelmininary heat treatment at 100°C for 20 minutes, the photoresist is removed by using acetone, methyl ethyl ketone (MEK) r alcoh l, and further heat treatm nt for baking is conducted at 150—200°C for one hour. As a result, a homogene us alignment area 31 and h me tropic alignment area 30 can b formed on the electrode substrate (electrode pattern 22 and substrate 21).

In this way, a fine pattern of the partial aligning treatment area which could not be attained by conventional photoresist printing techniques can be easily obtained with a high precision. For example, a line of 0.1 m/m can be formed within a precisiion of 5% or below. Further, a line of 0.1 m/m or below can be also easily obtained with practically satisfactory precision.

According to the prior art process, contrivances were necessary for obtaining a desired configuration of the electrode. However, there accrued many defectives such as poor etching, etc. during the fabrication of electrodes having fine or complicated shape, resulting in remarkably lowered yields. On the contrary, this invention can provide excellent effects such that the electrodes may be very rough in shape and therefore occurrence of such defectives can be readily avoided. Additionally, a display pattern of a complicated configuration which was very difficult to attain can be obtained very easily.

In conventional methods for practical alignment, high accuracy is required for registration of the upper and lower substrates at the partial aligning treatment portions. If there is positional discrepancy in the registration, the colored state is formed at the discrepancy position in case of the guest-host type display device, and therefore observation of the display is very difficult. In contrast, the display device of this invention is advantageous also in this respect; that is, since the partial aligning treatment may be applied onto the surface of one electrode substrate and a homogeneous aligning or homeotropic aligning treatment may be applied onto the surface of the other electrode substrate, the two substrates may be simply superimposed, and therefore no registration of the substrates at the position of the electrodes is necessary. Further, a very excellent display can be obtained.

CLAIMS

1. An electrooptical device comprising a liquid crystal and a dichroic dye disposed between a pair of opposed electrode substrates, characterized in that said liquid crystal has a homogeneous alignment region or twisted alignment region and a homootropic alignment region.

2. The electrooptical device according to Claim 1, wherein said liquid crystal is a nematic one having a positive dielectric anisotropy.

3. The electrooptical device according to Claim 1, wherein said homogeneous alignment region or twisted alignment region is formed so as to be in agreement with a predetermined display pattern.

4. The electrooptical device according to Claim 1, wherein said liquid crystal is a nematic one having a negative dielectric anisotropy.

5. The electrooptical device according to Claim 1, wherein said homeotropic alignment region is formed so as to be in agreement with a predetermined display pattern.

6. The electrooptical device according to Claim 1, wherein the molecular alignment of the liquid crystal in said homeotropic alignment region is controlled by a homeotropic aligning film formed on a photoresist.

7. The electrooptical device according to Claim 6, wherein said liquid crystal is a nematic one having a positive dielectric anisotropy.

8. The electrooptical device according to Claim 7, wherein the photoresist is formed on the area of the electrode substrate having no display electrode.

9. The electrooptical device according to Claim 1, wherein said dichroic dye is selected from anthraquinone type dye, cyanine type dye and azo type dye.

10. An electrooptical device comprising a liquid crystal and a dichroic dye disposed between a pair of opposed electrode substrates, characterized in that said liquid crystal has a homogeneous alignment region or twisted alignment region and a hybrid alignment region.

11. The electrooptical device according to Claim 10, wherein said liquid crystal is a nematic one having a positive dielectric anisotropy.

12. The electrooptical device according to Claim 10, wherein said liquid crystal is a nematic one having a negative dielectric anisotropy.

13. The electrooptical device according to Claim 10, wherein the liquid crystal has a hybrid alignment region.

14. The electrooptical device according to Claim 10, wherein said hybrid alignment region is formed so as to be in agreem nt with a predetermined display pattern.

15. The electro ptical device according to Claim 10, wher in the m l cular alignment of th liquid crystal in said hybrid alignm nt region is controlled by a homeotropic aligning film and a homogen ous aligning film on a photoresist.

16. The electrooptical device according to Claim 10, wherein said dichroic dye is selected from anthraquinone type dy , cyanine type dye and azo type dye.

17. A process for making an electrode substrate for use in an electr optical d vice comprising the steps of: forming a photoresist coating on an electrode substrate having a homogeneous aligning film,

exposing and developing the photoresist coating to form a mask, forming a homeotropic aligning film on the electrode substrate having the homogeneous aligning film and the mask, and removing the mask.

18. The process for making an electrode substrate for use in an electrooptical device according to Claim 17, wherein said photoresist coating is form d from a positive photoresist.

19. The pr cess for making an lectrod substrate for use in an el ctrooptical device according to Claim 17, wherein said homeotropic aligning film is formed on the area of the electrode substrate having no display electrode.

20. The process for making an electrode substrate for use in an electrooptical device according to Claim 17, wherein the homeotropic aligning film is formed by using a solution of the homeotropic aligning film-forming material in a solvent which does not erode said photoresist.

21. The process for making an electrode substrate for use in an electrooptical device according to Claim 20, wherein said homeotropic aligning film-forming material is a fluorine containing silane compound.

22. An electrooptical device in which a liquid crystal material is disposed in a space between opposed surfaces and in which at least one of said surfaces has respective portions treated to create in said material regions having different optical characteristics.

23. A device according to claim 22 wherein said surface treatment in said surface portions is such as to create in said material a homogeneous or a twisted alignment region and a homeotropic alignment region.

24. A device according to claim 22 wherein said surface treatment in said surface portions is such as to create in said material a homogeneous or a twisted alignment region and a hybrid alignment region.

25. An electrooptical display device in which a liquid crystal material is disposed in a space between opposed surfaces, means is provided for selectively applying an electric field across a portion of said space to control the display of a display pattern, and in which the display pattern is defined by differently treated surface regions of said opposed surfaces.

26. An electrooptical device substantially as hereinbefore described with reference to Figure 2A of the accompanying drawings.

27. An electrooptical device substantially as hereinbefore described with reference to Figure 2B of the accompanying drawings.

28. An electrooptical device substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

29. A method of making an electrode substrate for use in an electrooptical device, substantially as hereinbefore described with reference to Figures 4A to 4E of the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1983. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.